AMSR-E SWE Product Update

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Product version delivered: 1 June 2004

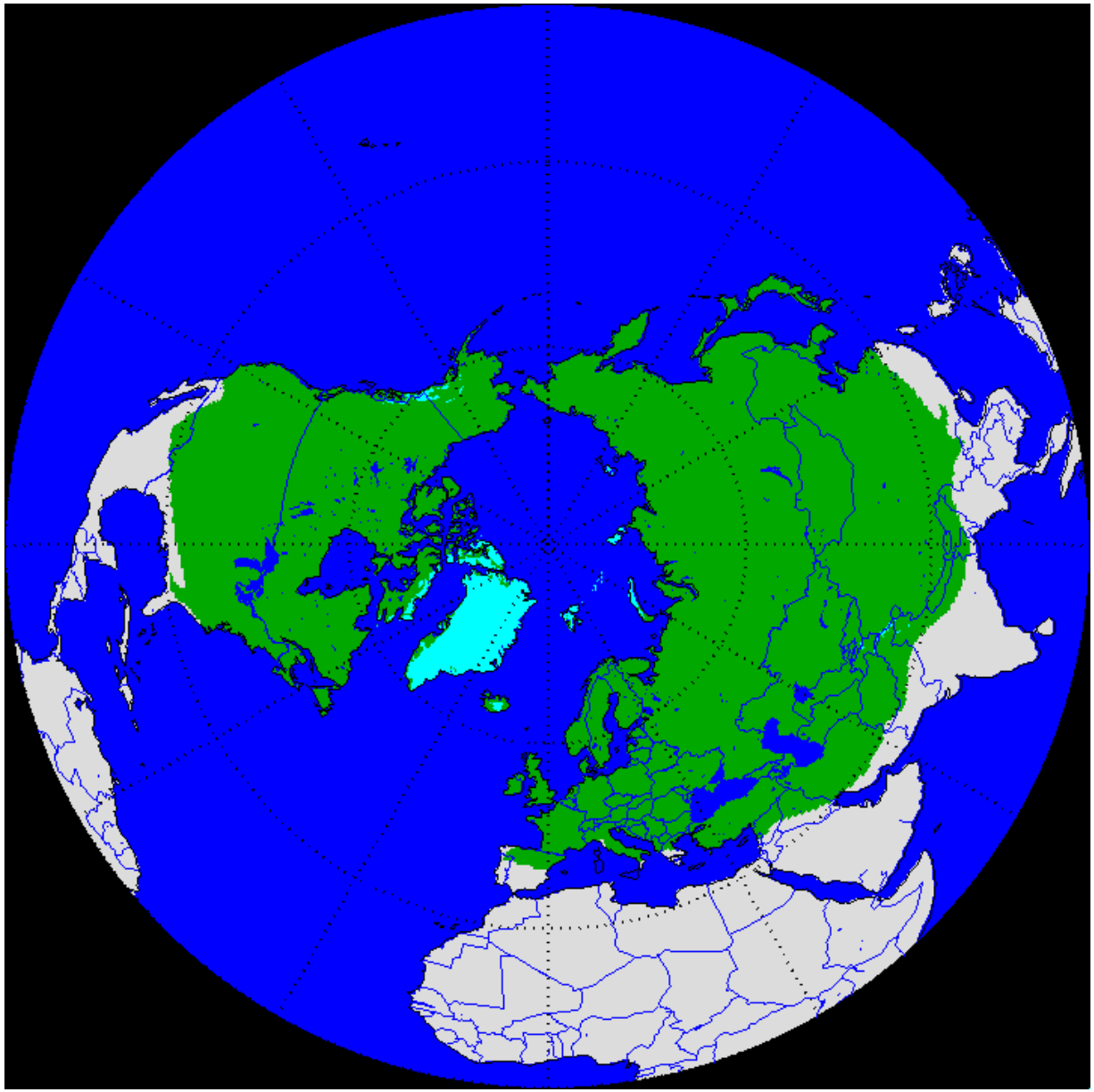
$$SWE = \frac{[4.8 \times (Tb18H - Tb36H)}{2 \times (1 - 0.2\,ff)} \quad \text{mm}$$

Time & space static coefficient (based on grain size 0.3 mm radius and density 0.3 g cm^{-3})

Scaling factor to enable SWE range of 1-480 mm

Forest fraction (derived from Robinson & Kukla, 1986)

Land/Water Masks



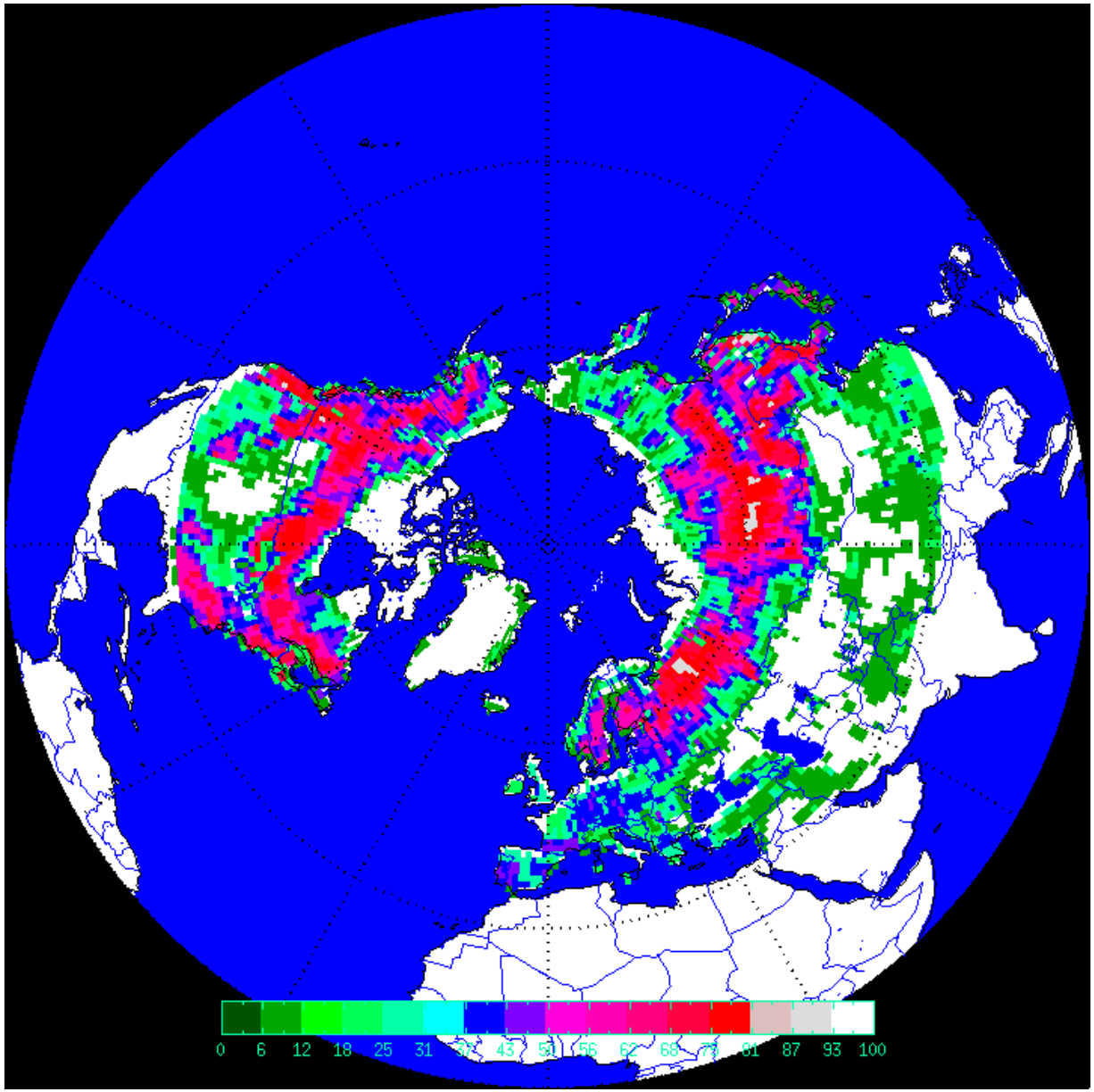
New Land, Ocean Coasts & Ice mask. Derived from MODIS MOD12Q1 IGBP land cover data (collection V004). If greater than 50 % of 1 km^2 water cover in a 25 x 25 km EASE-Grid pixel are water then water is flagged.

Source: NSIDC

Also, snow possible/ impossible data are shown (from Dewey and Heim, 1984).

Same is available for southern hemisphere.

Forest fraction data

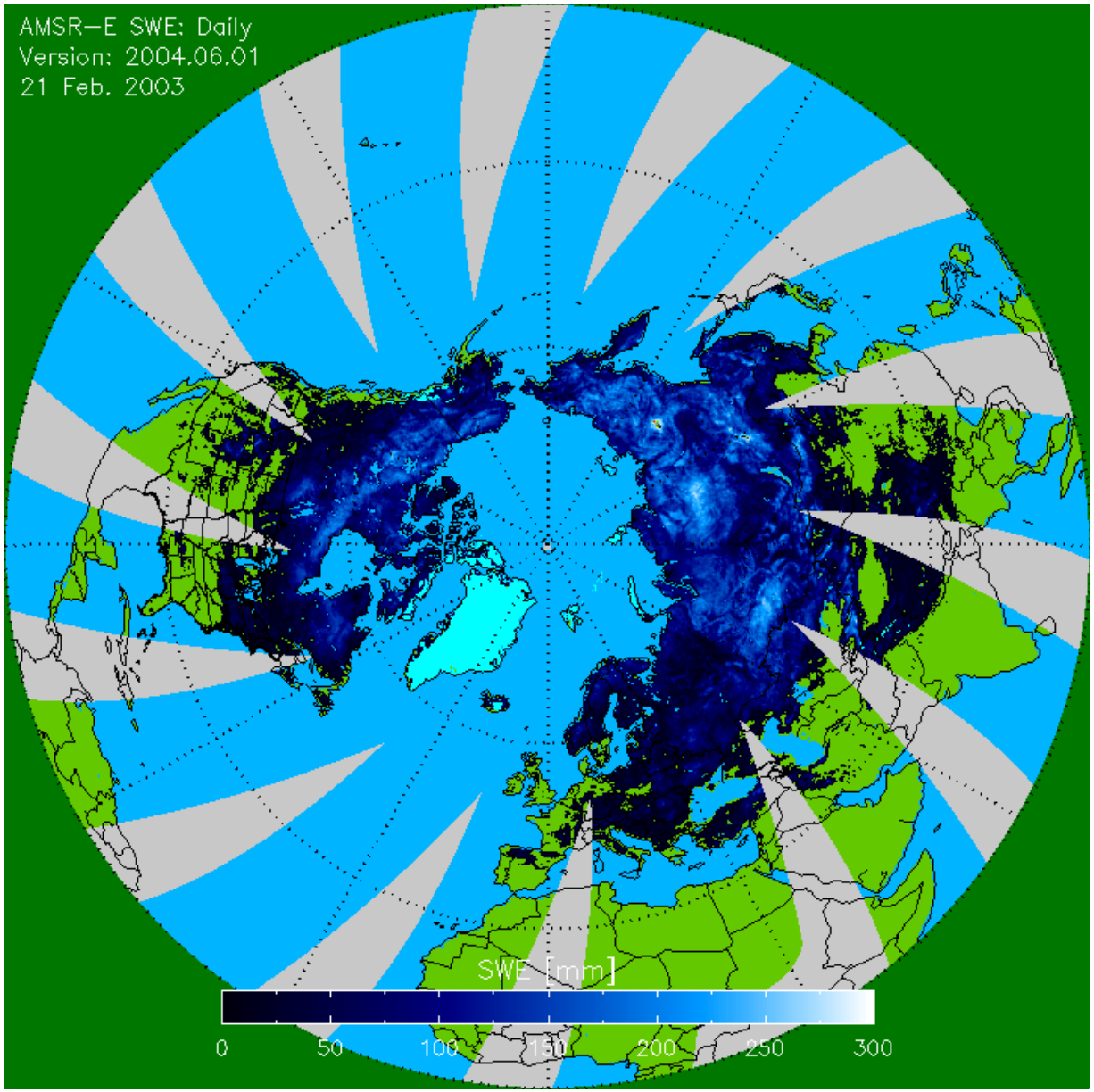


Forest fraction is calculated from VIS/IR reflectances and study by Robinson & Kukla, 1985. These data are derived from DMSP OLS data and are dated.

NB. Forest correction is conservative as we are testing this further (1 - 0.2*ff*).

Same is available for southern hemisphere.

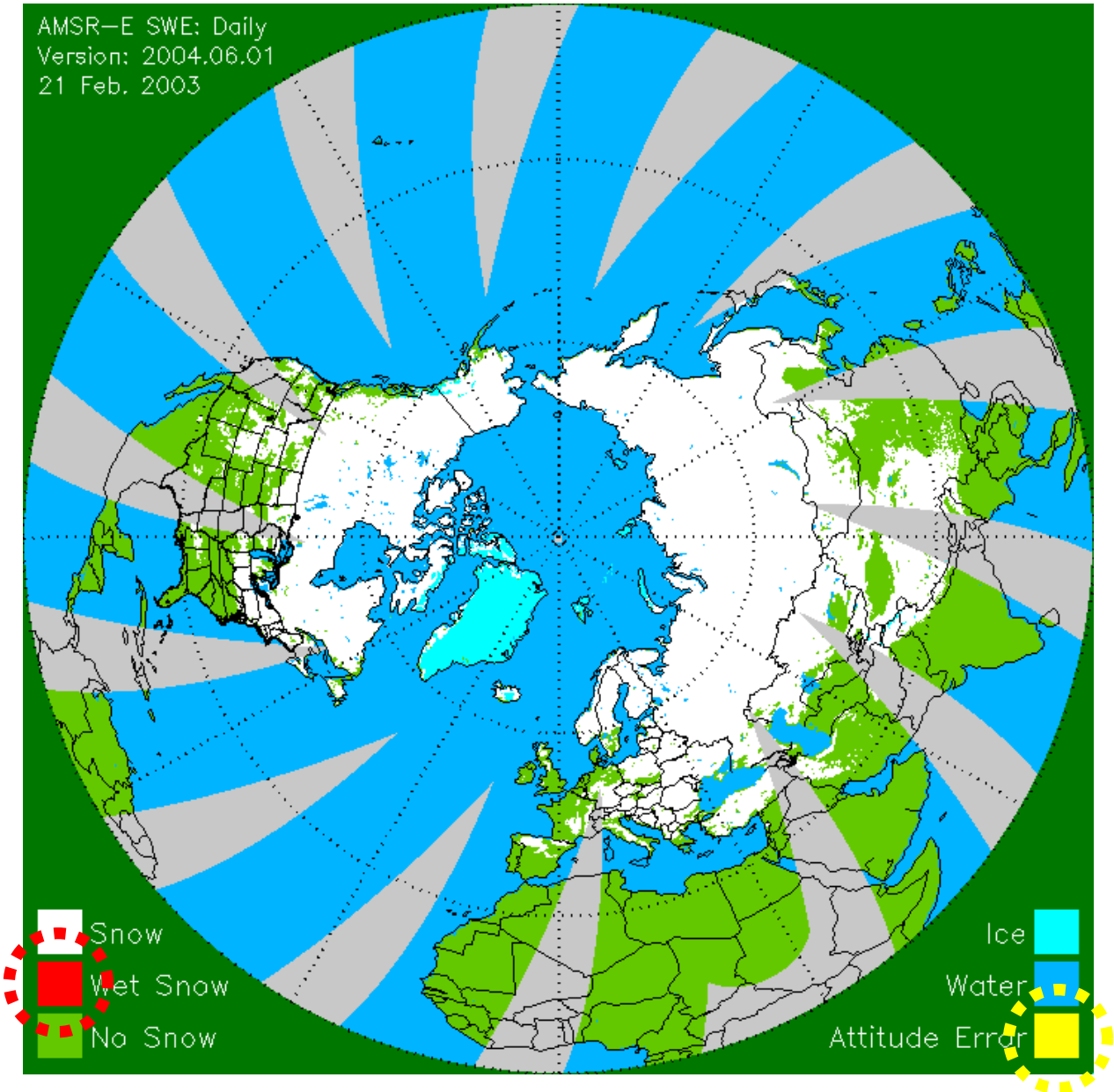
Example of SWE estimation



21 February, 2003.

SWE has been re-quantized from 1-240 mm (old) to 1-480 mm (new).

Example of SWE Flags



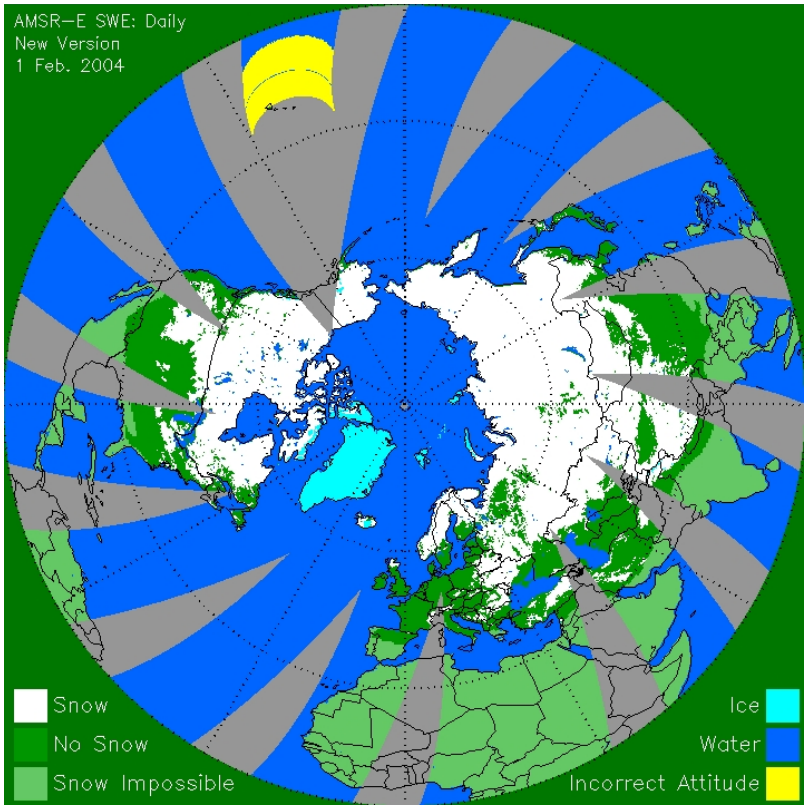
21 February, 2003.

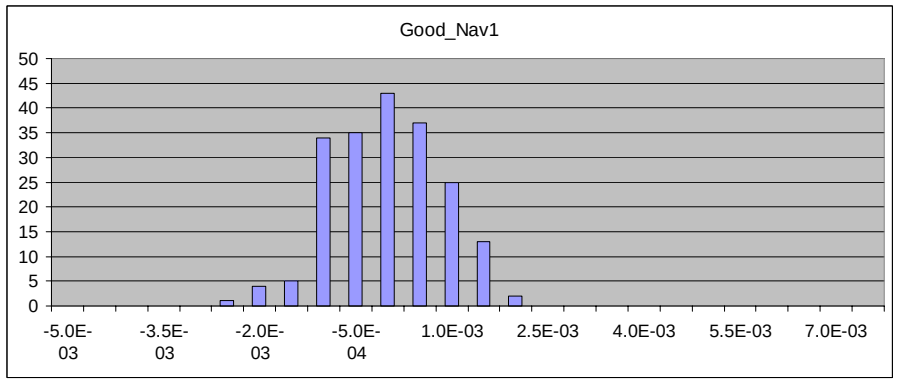
Currently the wet snow flag is under testing.

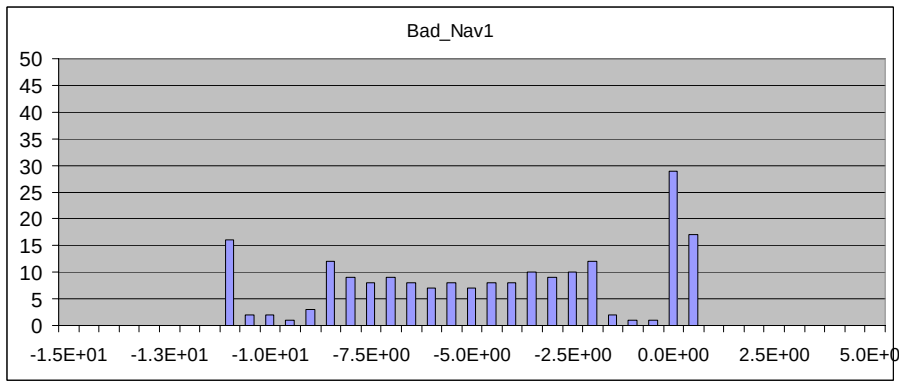
The attitude error flag was applied after some erroneous estimates were obtained in Feb 2004.

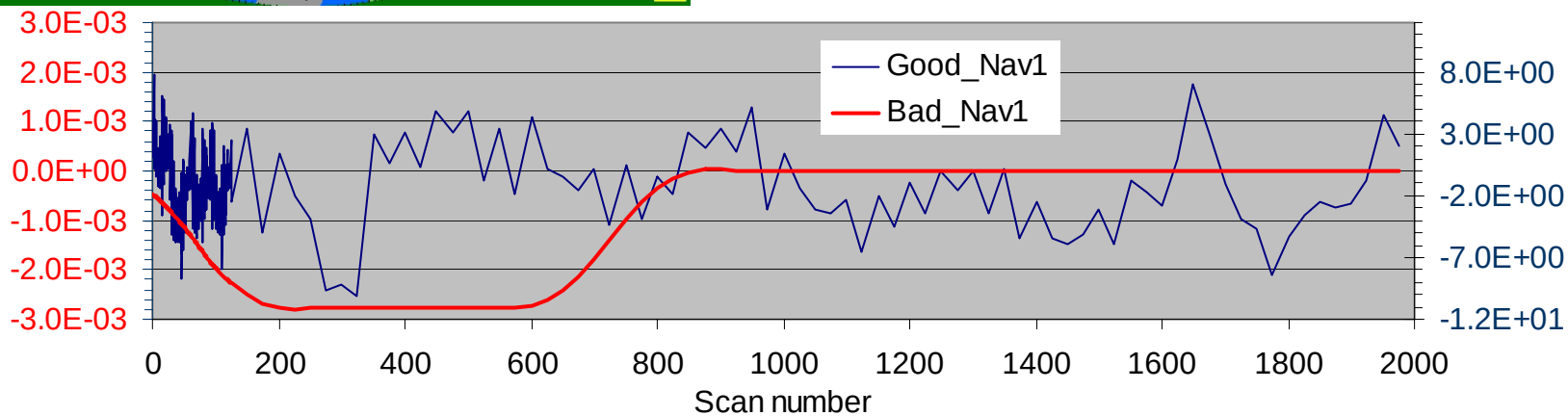
Attitude error flag

The attitude error flag was applied after some erroneous estimates were obtained in Feb 2004. (+/- 0.015 Roll :: +/- 0.006 Pitch)





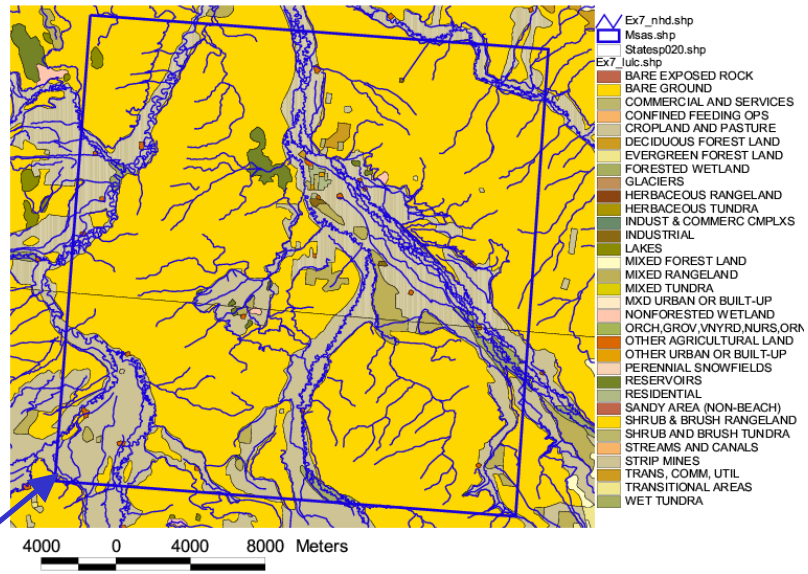


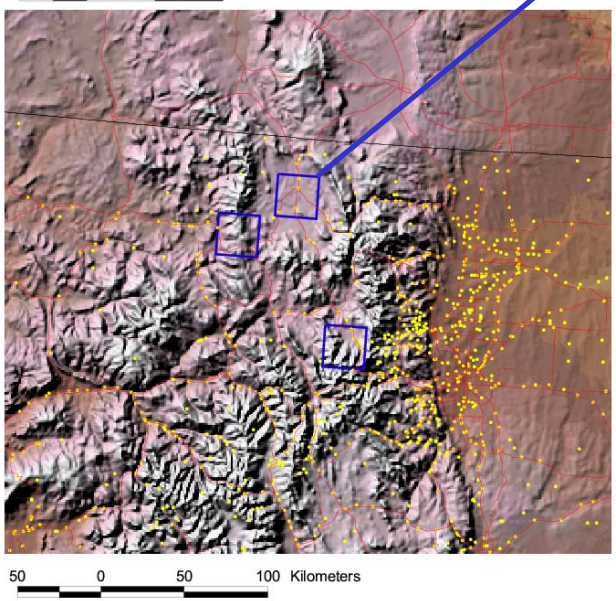


AMSR-E SWE Validation

- CLPX field study data.
- GAME/CEOP field data.

CLPX domain data: the North Park MSA,CO.

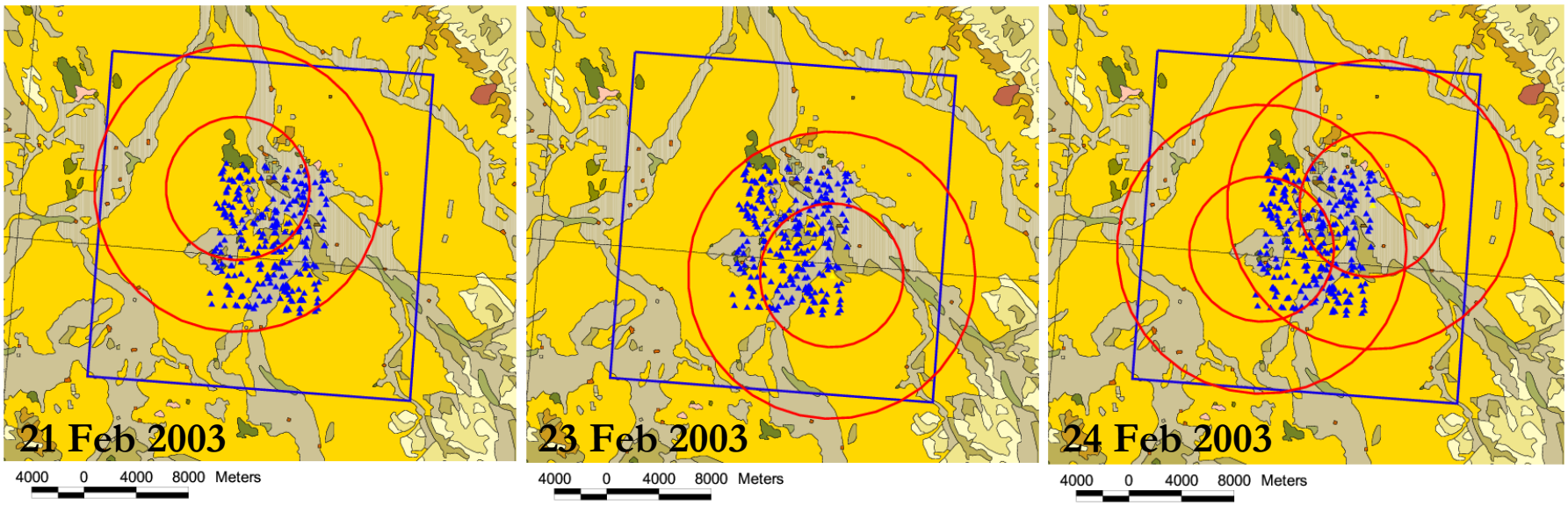




North Park Mesocell Study Area (MSA):

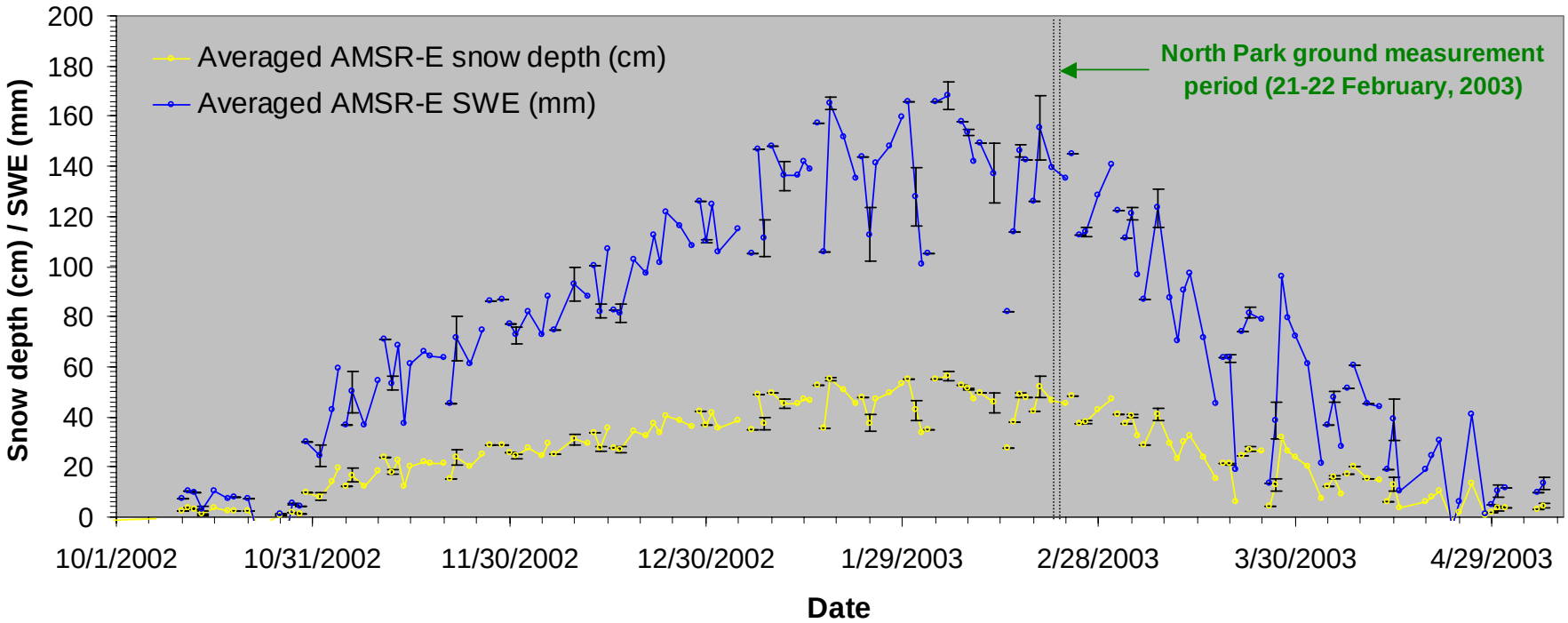
- broad, high-elevation parkland approximately 40 km in diameter.
- mean elevation of 2499-m and most of the MSA has very low relief (total elevation range of 312-m).
- inter-mountain glacial basin that opens north into Wyoming. The surrounding high mountain areas develop deep snow packs in winter as a result of significant orographic precipitation effects, but **relatively little snow accumulates in North Park itself** due to the precipitation "shadow" caused by the surrounding mountains.

1 winter season of AMSR-E samples over North Park, CO, 1 Oct. 2002-30 Apr. 2003



Blue symbols represent centres of AMSR-E 3dB IFOVs
within ~5km of MSA centre for the entire winter of 2002-2003.
Red circles approximate AMSR-E IFOVs at 18 & 36 GHz.
(L2A native channel IFOV spatial resolutions used – not resampled)

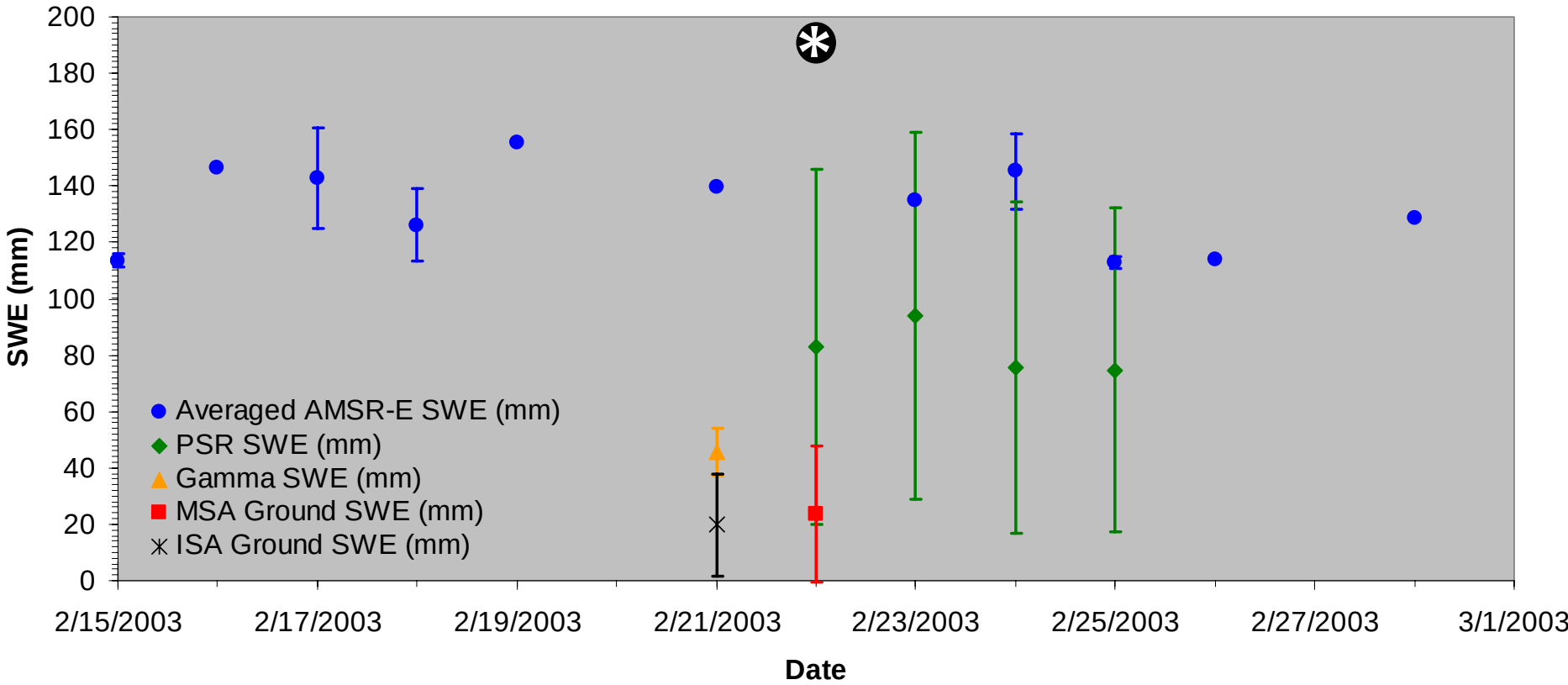
Variations of snow depth & SWE for North Park. Error bars represent standard deviation for EASE-grid cell with >1 AMSR-E observation



Average SWE [=4.8*(Tb18H-Tb37H)/2*(1-0.2*ff) where ff = 0]

- 2/21/03 = 139.7 mm
- 2/22/03 = Swath Gap
- 2/23/03 = 134.9 mm
- 2/24/03 = 145.3 mm
- 2/25/03 = 112.8 mm

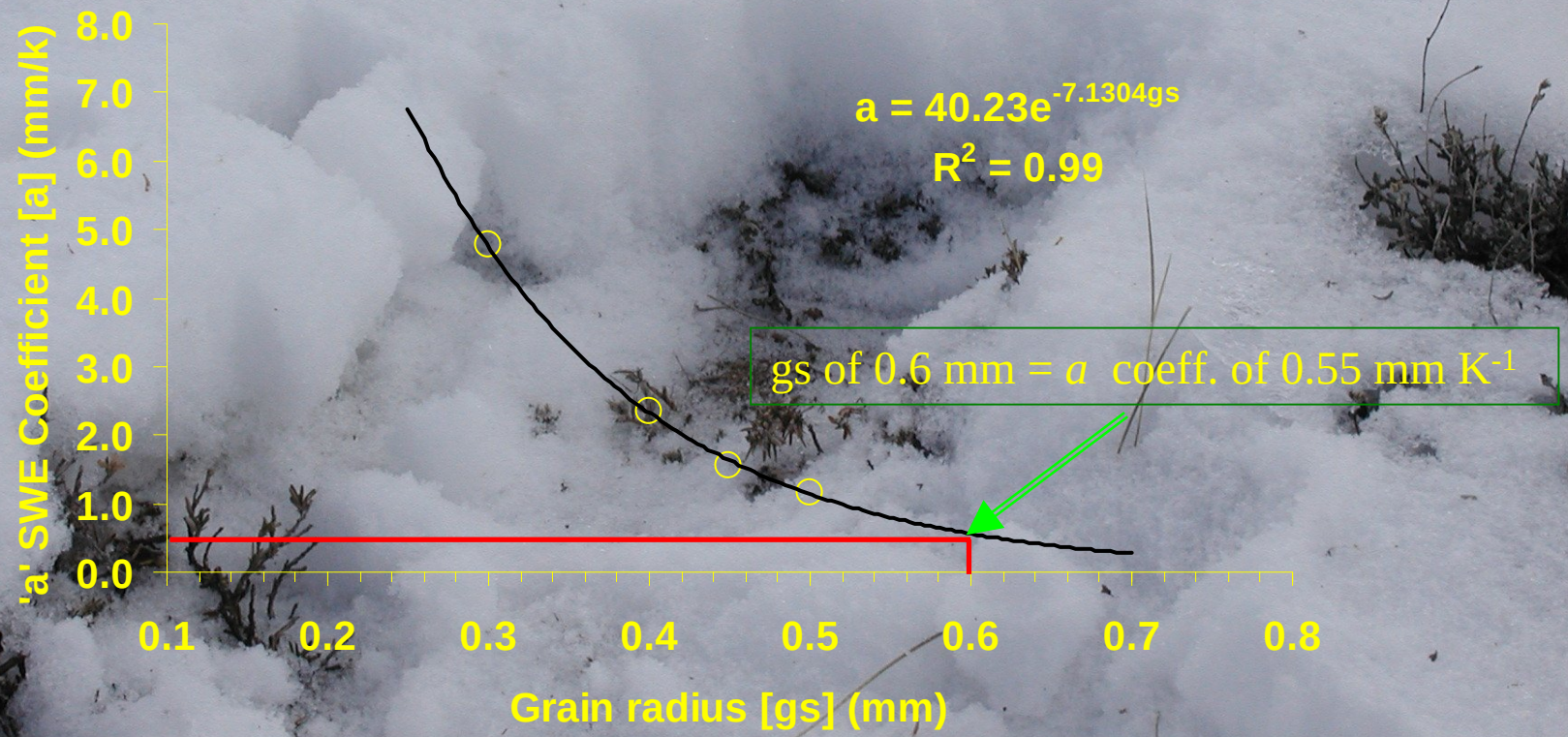
Comparison between SWE estimates



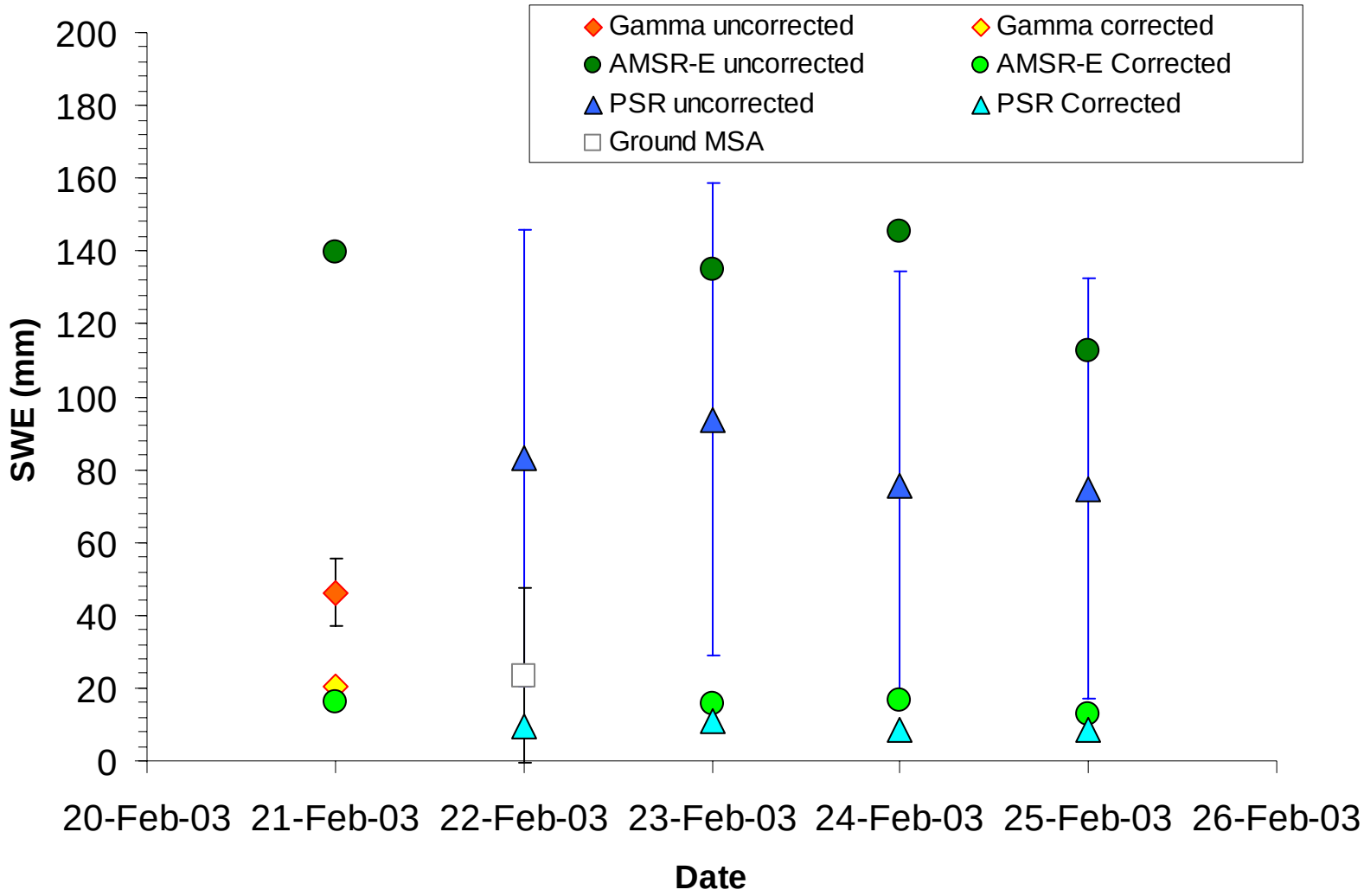
- Gamma (46 mm) – uncorrected for soil moisture
- Ground (MSA: 24 mm, ISA: 20 mm) - probable underestimation (sampling)
- PSR - overestimation
- AMSR-E - overestimation

Cause of AMSR-E (& PSR) over-estimation: Grain Size

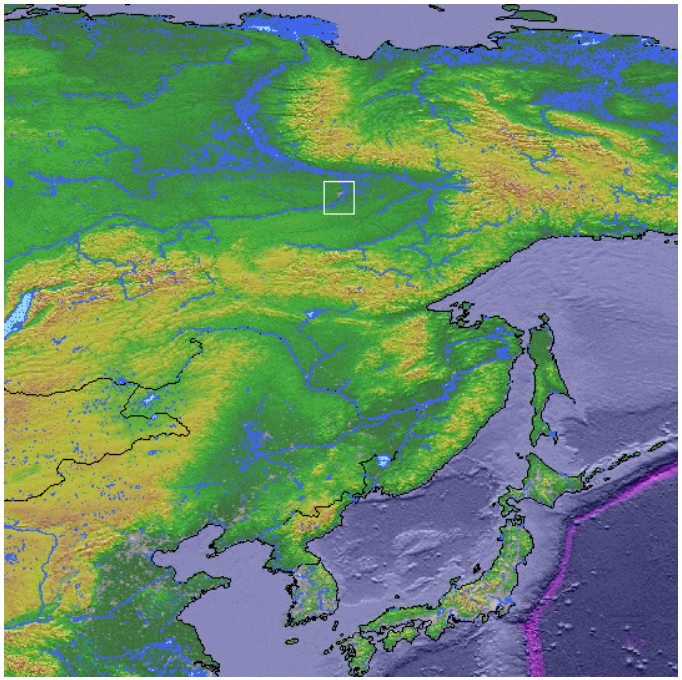
- Grain size parameterizes the retrieval algorithm SWE = *a* * (Tb18h-Tb36h)
- Coefficient *a* (= 4.8) is inversely related to grain radius. For North Park the measured grain radii were 0.7 mm and 0.5 mm for ISA and MSAs respectively (average 0.6).
- Unpubl. radiative transfer modelling research by Foster & Chang shows that for a grain radius of 0.6 mm, *a* = 0.55 mm K^{-1}.

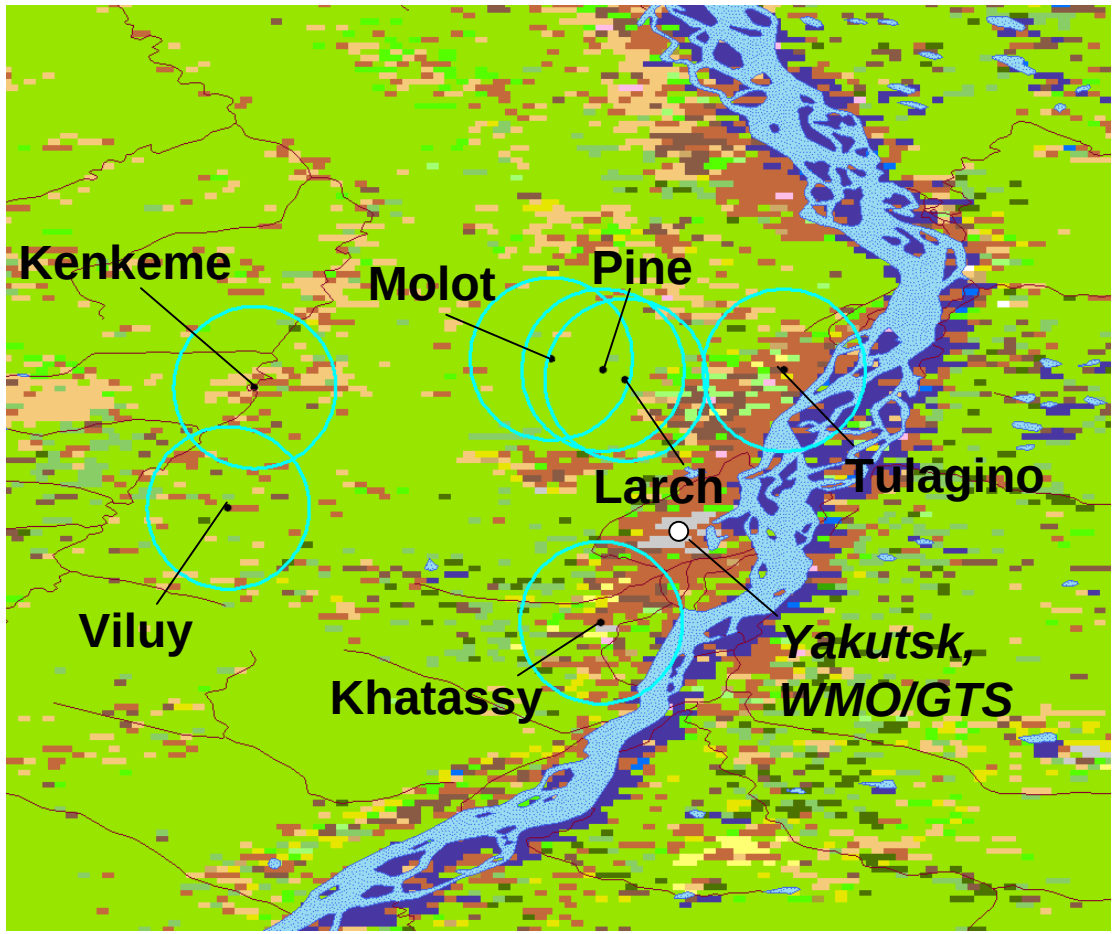


Corrected AMSR-E (& PSR) for grain size



GAME/CEOP domain data: Yakutsk, Siberia.



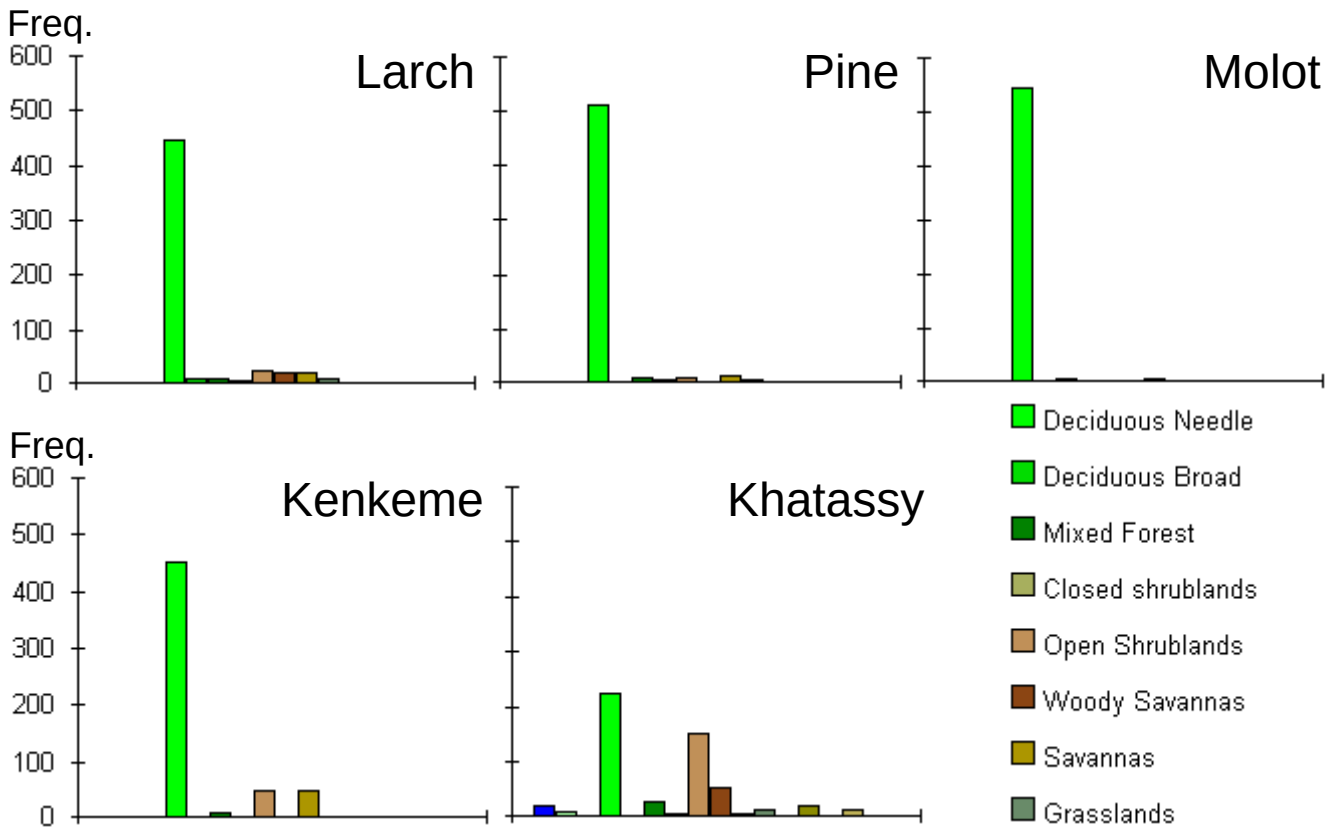


- 0 Water
- 1 Evergreen Needle Leaf
- 2 Evergreen Broad Leaf
- 3 Deciduous Needle Leaf
- 4 Deciduous Broad Leaf
- 5 Mixed Forest
- 6 Closed shrub
- 7 Open Shrub
- 8 Woody Savannas
- 9 Savannas
- 10 Grassland
- 11 Permanent Wetlands

0 25 km

Comparisons of AMSR-E estimates of **snow depth** with GAME/CEOP measurements

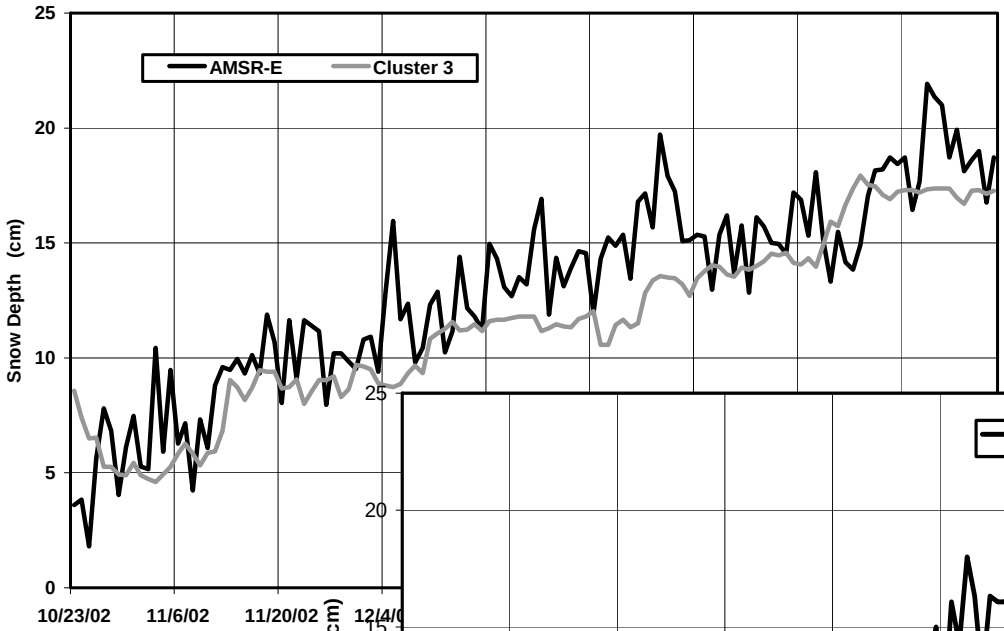
Dominant land cover categories (MODIS MOD12Q1) for each site for each IFOV.



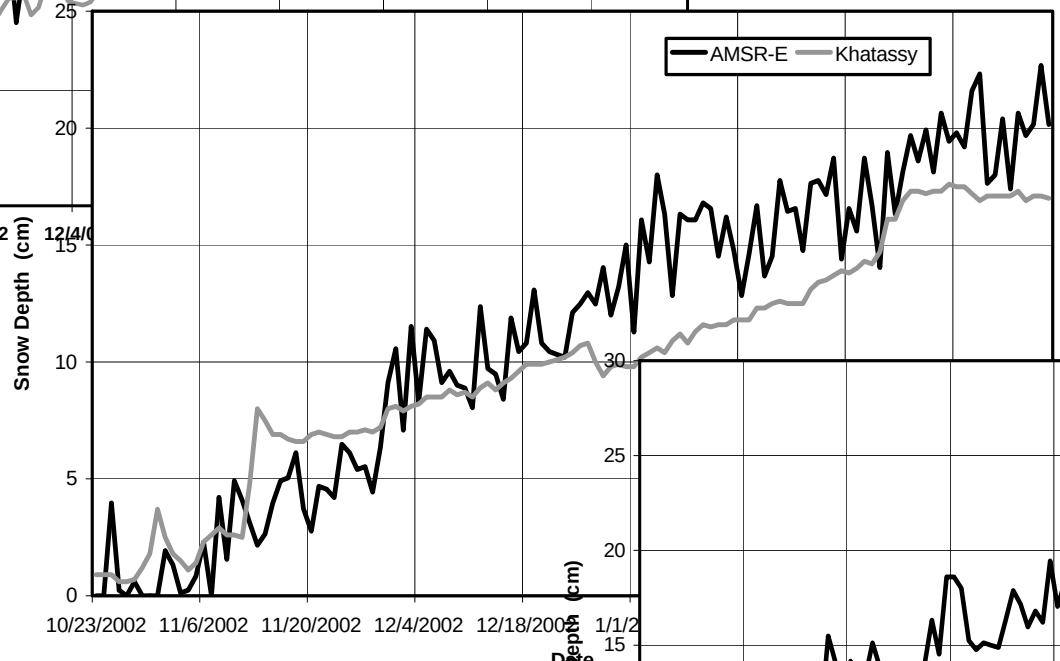
Adjusted baseline algorithm

$$SWE = \frac{[1.2 \times (Tb18H - Tb36H)}{2 \times (1 - 0.2\,ff)} \quad \text{mm}$$

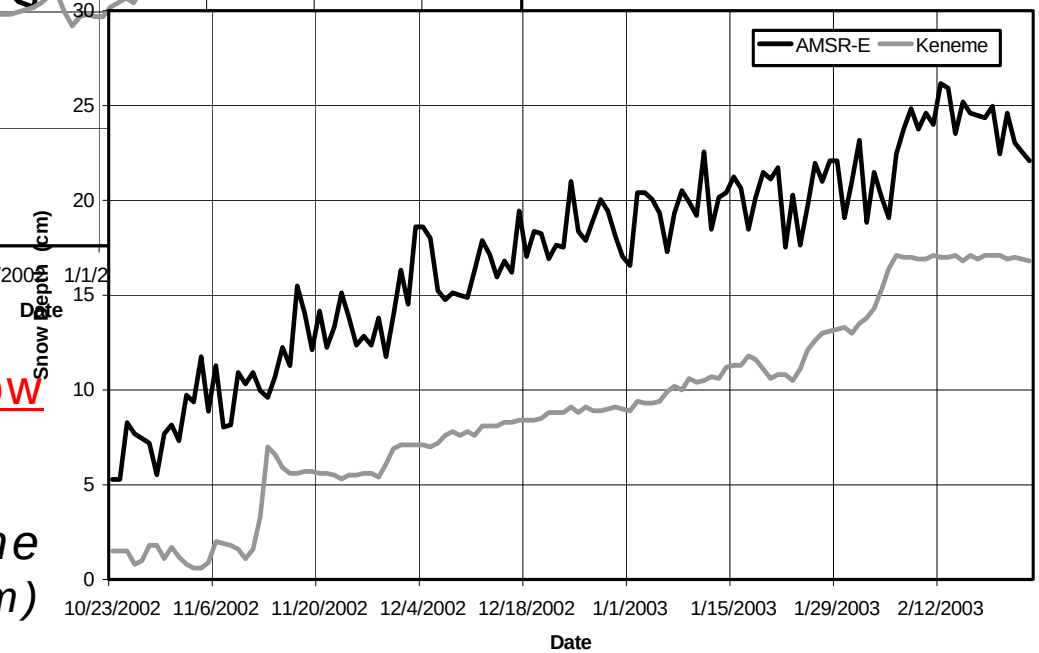
Adjusted coefficient coefficient (based on larger estimated grain size 0.34 mm radius)



Larch, Pine, Molot
(mean error = 1.5 cm)



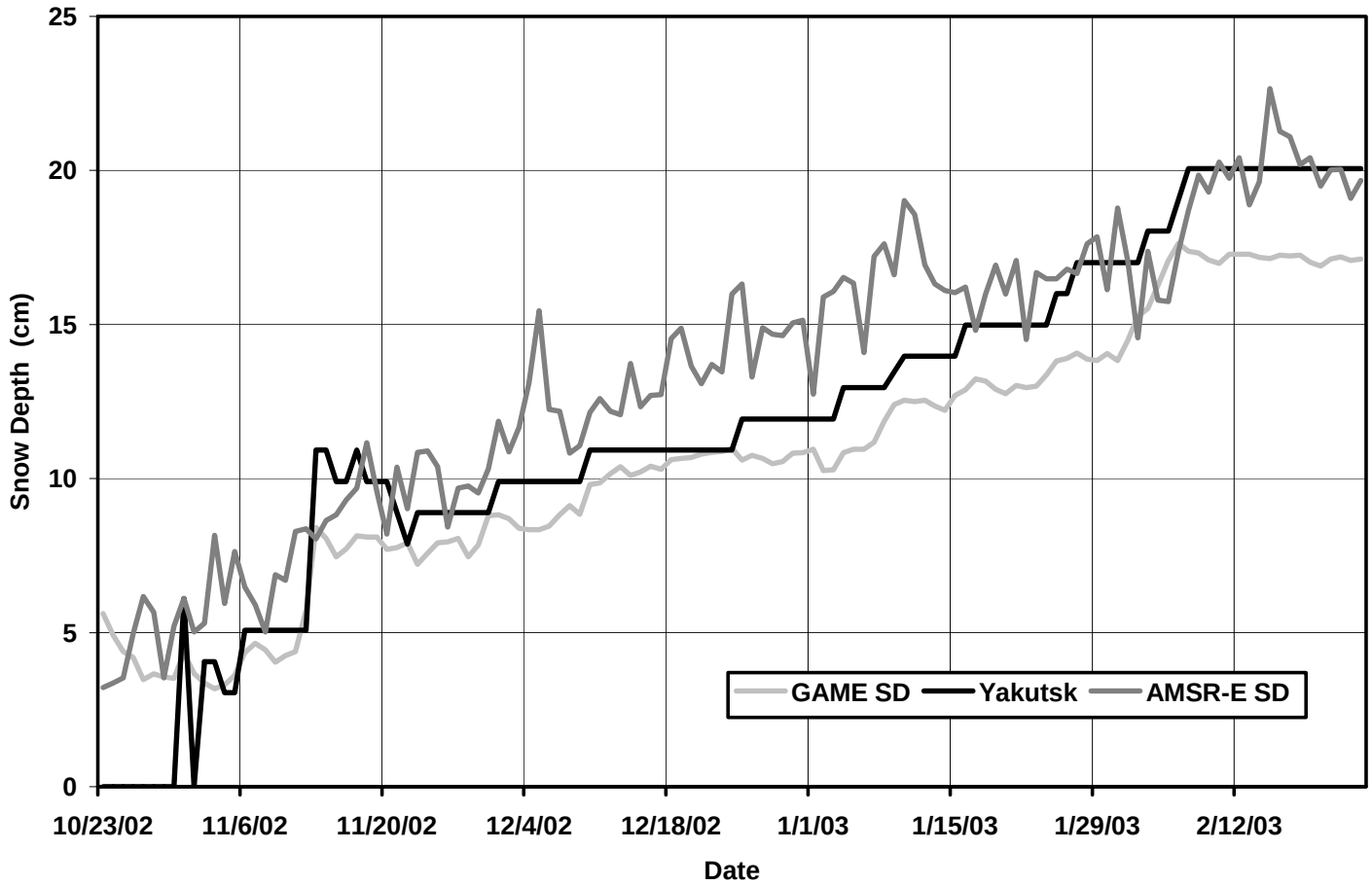
Khatassy
(mean error = 1.4 cm)



Stated target AMSR-E mean snow depth error = 7.0 cm

Kenkeme
(mean error = 8.0 cm)

Comparison of AMSR-E with Yakutsk WMO GTS site.



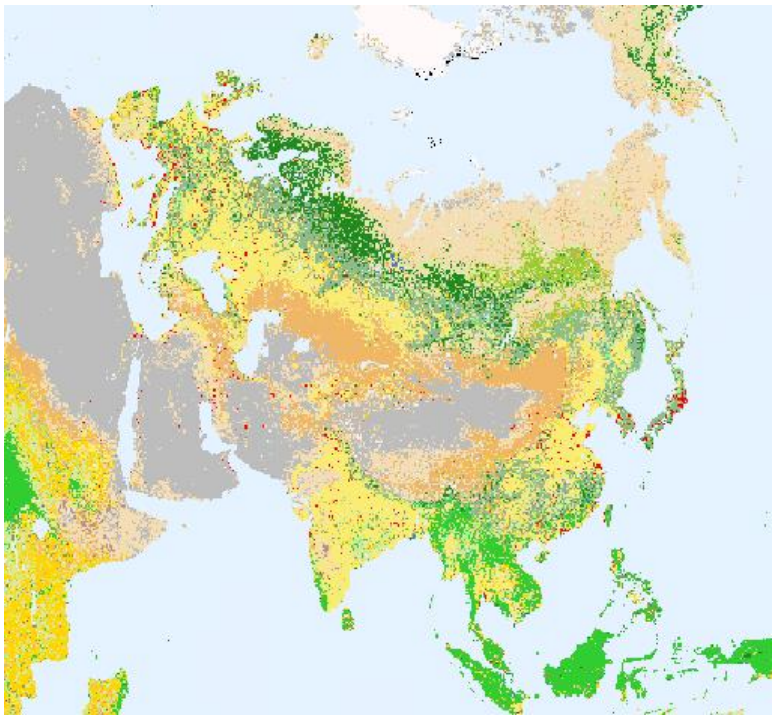
This is a great site for AMSR-E validation of snow depth estimates.

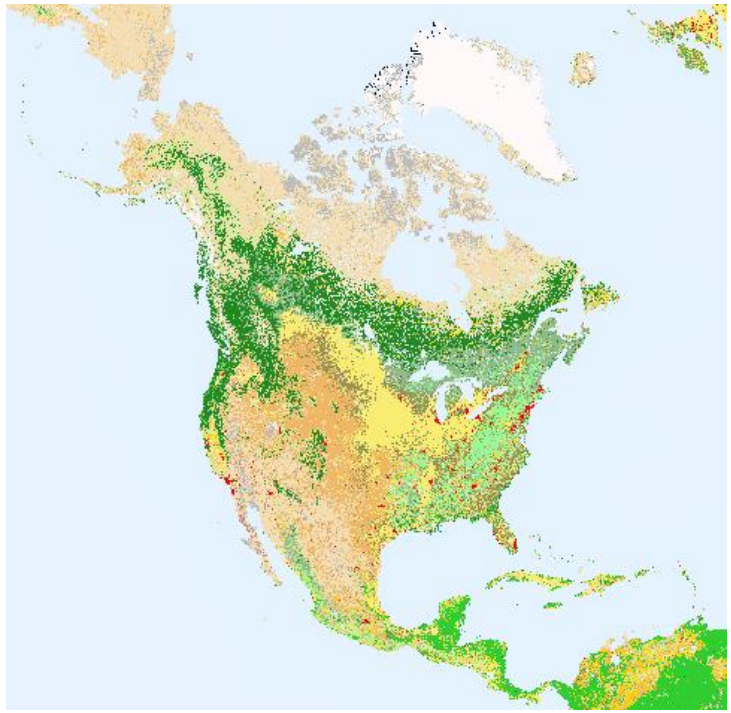
AMSR-E SWE Algorithm Development

- Developing flags to identify false snow scatterers (e.g. rain , frozen ground and wet snow).
- Improved representation of forest to better reduce attenuation effects of microwave signal from snow in forested areas.
- Estimation of grain size to add dynamism of the *a* parameter in baseline algorithm.

Improved and updated forest representation

- MODIS LUCC MOD12Q1 delivery V004
- 1 km^2 data set from land team on MODIS



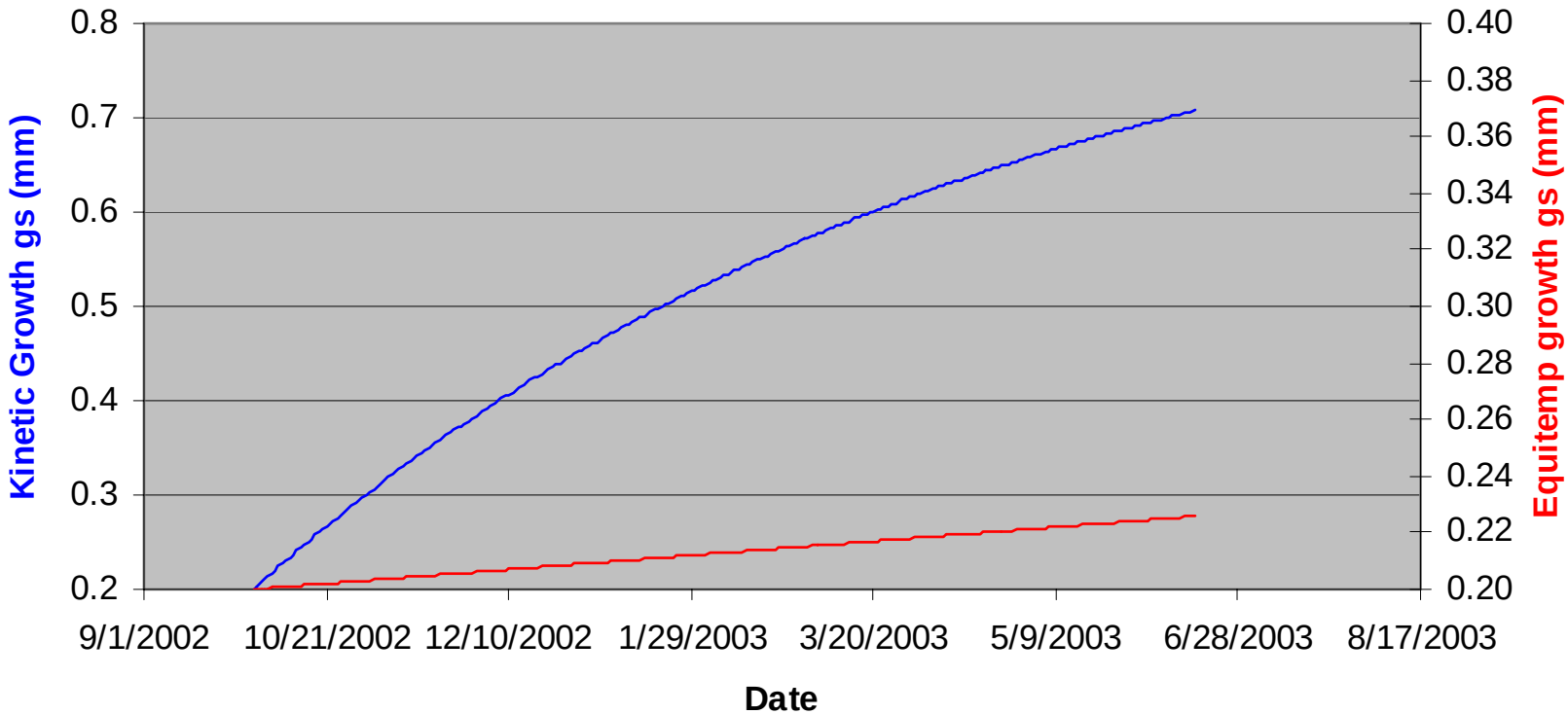


Courtesy of Boston University

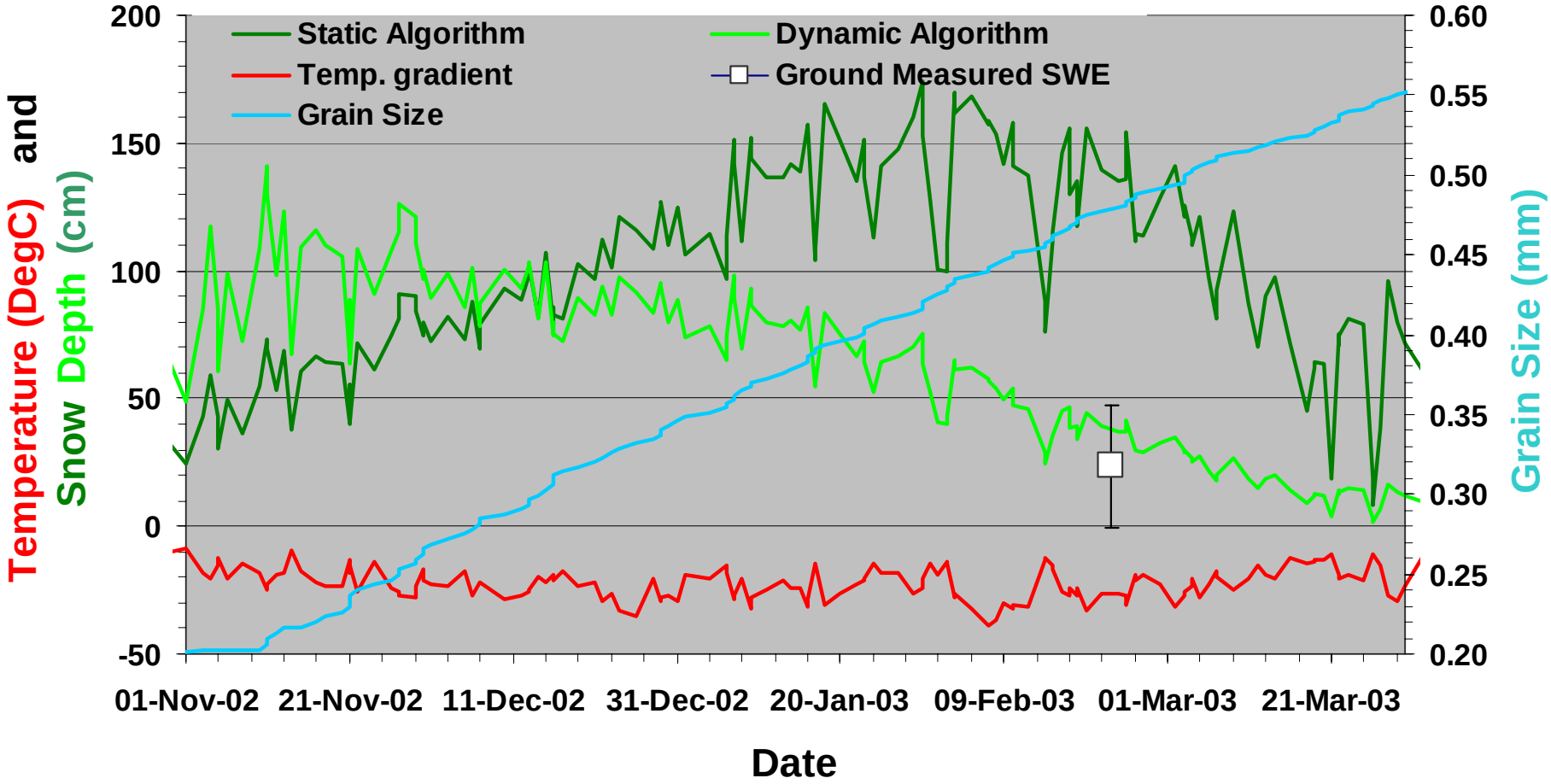
Developing improved correction approach based on alternative methodologies: e.g. reflectance relating to gaps using multi-angular information, perhaps even microwave response in higher frequencies.

Estimation of grain size

- New simple approach to estimate grain growth (Sturm and Benson, J. Glaciology 1997)
  Kinetic Growth (fast, large) gs = $r_\infty - (r_\infty - r_0) \exp^{-\alpha t}$ *where* r_∞ = max gs, r_0 = min gs, α = growth rate and t = age in days of snow pack.
  Equi-temperature growth (slow) $gs_{t-1} = gs_t + 0.0001$ mm
- Use estimated temperature history for past 10 days to determine growth trajectory.
  Surface air temp = 58.1-0.4*Tb19v+1.2Tb22v-0.4*Tb37h+0.4*Tb85v (K)
  (Derived from 100 stations in n. hemisphere for 4 years (accuracy to 6K in winter) and SSM/I data)
- Upper and lower growth limits are critical. (for details see Kelly et al. TGRS 2003)



- Example for North Park, CO, CLPX IOP-3



Planned update for next delivery (1 Sept, 2003)

- Complete implementation of flags.
- QC confidence scheme for SWE estimates based on validation experiences.

Outlook.

- Advance validation effort from local through regional scales (CLPX, GAME/CEOP, Canadian (MSC) & French (CESBIO) collaboration.
- Algorithm Developments
  - Improve forest correction
  - Develop more dynamic representation of snow grain size.

Finally, but most importantly, this work is only possible thanks to the numerous truly ground-breaking achievements in the fields of microwave remote sensing and hydrology, and from the boundless critical scientific insights of Alfred T.C. Chang (1942 – 2004), friend and respected colleague…….

Alfred T.C. Chang Memorial Symposium
12 October 2004

In memory of Dr. Alfred T.C. Chang's contribution to Earth Science, there will be a NASA, USDA & IEEE sponsored memorial symposium held at the Visitor Center at NASA's Goddard Space Flight Center in Greenbelt, Maryland, on 12 October, 2004. The symposium, entitled The Alfred T. C. Chang Memorial Symposium, will consist of invited and contributed presentations dealing with microwave remote sensing.

For further information please see: http://neptune.gsfc.nasa.gov/chang